Literature Review for the project: "Increasing the Productivity of Improved Pastures by the Sustainable Management of Native Vegetation Regrowth"

The aim of this project is to provide management options for controlling native vegetation regrowth in improved pastures. The control options for native vegetation regrowth in improved pastures are fairly limited. If the improved pasture contains any legume it cuts out the use of broad acre application of broad leaf herbicides. However if the improved pasture is comprised solely of grasses the number of control options is increased. The use of most mechanical controls is also limited as blade ploughing or the use of a one way plough may necessitate the re-planting of the pasture. The need to re-plant would increase the cost of the native vegetation control quite significantly.

Within the two districts there are also large areas of cleared land under native pasture that are experiencing problems with native vegetation regrowth. Control options for native vegetation regrowth in native pastures will be considered even though they may not be relevant for improved pastures.

There are three questions that need to be answered in relation to the problem of native vegetation regrowth. These are:

1. What is the extent of the problem?
2. How does native vegetation regrowth impact on farming operations?
3. Why does native vegetation regrowth become a problem?

The next two areas to be discussed are:

4. The invasion of grasslands by woody plants and the thickening of woodlands and forests.
5. Options for controlling or managing native vegetation regrowth.

What is the extent of the problem?

Native vegetation regrowth in both improved and native pastures in the Top End has been identified as the major issue affecting productivity, by two regional best practice groups, the Douglas Daly and the Mary River Producer Groups. In a meeting of the Douglas Daly Producer Group in late 2006, producers undertook an issues listing and priority rating exercise. The management of native regrowth in improved pastures was rated as the highest priority issue affecting their profitability and sustainability. Of the 215,000 hectares cleared (4.1% of the total area) in the Daly River catchment, approximately 50,000 hectares has been sown to perennial improved pasture or is being annually cropped. A very large proportion of the remaining area (~ 165,000 hectares) has returned to native regrowth (Eastick *et al* 2007a and 2007b). The Mary River Producer Group undertook a similar exercise in early 2007 where again this issue rated highly. The total area of the Mary River District is approximately 345,000 ha and of the 10,500 ha that has been cleared, approximately 7,000 ha are affected by native vegetation regrowth.

How does native vegetation regrowth impact on farming operations?

Native vegetation regrowth (NVR) impacts on farming operations in many ways. Initially its impact can be quite minor and of little concern. However as its size and density increase it can become a major problem. Many people are unaware that the NVR is gradually increasing in both density and size. It is a good idea to establish photo points to provide a timeline to highlight changes (Michelmore, 1997, T. Moran. pers. comm.). As with all weeds, which is effectively what NVR is, it is better to control them earlier rather than later. It is stated by many researchers that the control of NVR is much easier and cheaper in the first two years (Monaco *et al* 2002, Dow, DuPont). After that time the costs of control are much higher and the chances of success are considerably less.

Pasture yield. The actual effect of NVR on pasture production has never been quantified in either the Douglas Daly or the Mary River districts. However research in other areas has shown that as there is an increase woody weed, shrub or tree numbers there is a decrease in pasture production. Research in a variety of environments in Queensland has shown that very low tree densities can significantly depress pasture yield. The effect of a given number of trees increases as fertility and rainfall decrease. The effect is best shown through tree basal area rather than the number of plants or stems per hectare (Back *et al.* 2009, cf. McIvor 2006a) The converse is also true in that after clearing of woodlands or forests there is a considerable increase in pasture yield (Walker *et al.* 1972; Beale 1973; Gillard 1979; Walker *et al* 1985, Walker *et al* 1986; Belsky *et al* 1987; Carter *et al* 1988; Winter *et al.* 1989; Gardener *et al*, 1990; Scanlan and Burrows 1990; Murphy *et al*, 1993, Scanlan and McKeon, 1993; Dyer *et al.* 1997; Scholes, 1997; Café *et al*, 1999; Burrows 2001; Scanlan 2002; Dyer *et al.* 2004; Smit, 2005; Davidson *et* al 2006; Back *et al.* 2009). This increase initially spikes due to an increase in nutrient availability through nutrients released from the burnt timber. However over time it gradually decreases until it reaches a sustained level which is still well above the original pasture yield of the uncleared land (Dyer *et al.* 2004).

Trial work carried out in both Katherine and the VRD has shown that the principal limiting factor in pasture production on native pasture in the higher rainfall areas is the availability of nutrients, specifically nitrogen (Dyer *et al.* 2004). With the removal of trees there was a significant rise in pasture yield. This ongoing trial still demonstrates an increase in pasture production up to the present, 10 years later. As the Douglas Daly and Mary River districts are in a higher rainfall area this result should be applicable to both districts. The pasture in the trial sites was not grazed. Whether the offtake of nitrogen through grazing would alter the results is not known. There are two options to replace the nitrogen if its deficiency is impacting on pasture production. The first would be to incorporate a legume into the improved pasture. The second option would be to feed a nitrogen rich supplement to the cattle. This would be distributed throughout the paddock as the cattle grazed.

Some people do not consider NVR to be a problem. One producer is satisfied with having to chain the NVR every 4-5 years and then just let it lay (M. Williams pers.comm.). The cost of this operation averaged over 4-5 years is minimal. This operation however was undertaken on native pasture. The increase in production from treed to cleared land on native pasture is much less than the increase in production from treed native pasture to cleared land with improved pasture. The increase is even more pronounced when the improved pasture is fertilised. The principal agronomist for the Department of Regional Development, Primary Industry, Fisheries and Resources advises that for the Douglas Daly district the carrying capacity on uncleared native pasture is 1 head/12-16ha. On cleared land with improved pasture the carrying capacity is 1 head/3ha and on cleared land with improved pasture with fertiliser the carrying capacity increases to 1 head/ha with a marked increase in weight gain per head (A.Cameron pers. comm.).

Harbouring of pests. NVR provides shelter for pests of crops and grasslands as well as feral animals. Thicker NVR provides an ideal retreat for feral pigs often next to areas of cropping or improved pasture. Agile wallabies are also found in increasing numbers sheltering in NVR next to improved pastures (Howie pers comm., Shotton pers comm.).

Impeding the mustering of stock. NVR increases the difficulty of mustering cattle. It allows cattle to break away from the herd and also to avoid detection. NVR often necessitates the use of a helicopter to flush cattle out of thicker patches (Dyer *et al.* 2004).

Trafficability of the area. Thicker NVR may totally exclude vehicular traffic making the management of the property much harder. It can lead to increases in maintenance costs with increased punctures and also with smaller stems piercing the radiator.

Difficulty in spraying weeds using a ground rig. Taller NVR in a pasture impedes spraying operations using boom sprayers. The suckers tend to snap of the nozzles or nozzle assemblies making the use of ground rigs almost impossible without the use of protective shrouds. To avoid smaller suckers the boom is often lifted above its optimum working height leading to a poorer kill on the targeted weeds. The NVR also bends the arms of larger boom sprays back necessitating a pause in operations while the arms are reset.

Toxicity of some plants. Ironwood (*Erythrophleum chlorostachys*) and the Zamia palm (*Cycas armstrongii.*) are very toxic to cattle. The poisonous compound in Ironwood is an alkaloid: erythrophleine. The poisonous compound in Zamia palm is a glycoside: cycasin (Mitchell 1979). The toxicity of ironwood is demonstrated by its effect on goats. One ironwood leaf is enough to kill a goat (A Cameron pers. comm.).

Aesthetics. Many property owners prefer paddocks to have no NVR at all. This decision is often based purely on an aesthetic appeal rather than for production or economic reasons. They do not consider the cost of control as part of the farming operation but rather as a lifestyle choice.

Why does native vegetation regrowth become a problem?

Regrowth of native vegetation following land clearing has emerged as a serious problem in the Mary River and Douglas Daly districts. The regrowth in these areas varies from scattered isolated small plants to thick impenetrable scrub.

There is no particular land type that is more affected than any other. The main point seems to be that if land was originally forest or woodland it will always tend back to that condition. Its ability to return to a treed state depends on several factors.

The first factor is the quality of the original clearing. If steps are taken to ensure the removal of all stumps, roots and lignotubers in the first instance the reduction in regrowth is nearly total. Any seedlings which emerge can be controlled with the fire that is used to remove the bulk of the felled timber. If the timber has been windrowed it will be necessary to wait for the seedlings to emerge and then kill them when cultivating the seed bed for planting the improved pasture. Another option is to crop the area for 2-3 years using zero till. The herbicides used will also kill any small regrowth. Once the seed bank has depleted it would be safe to plant the improved pasture. Areas cleared by ADMA (Agricultural Development and Marketing Authority) in the 1980s showed very little regrowth. One of the main reasons was the use of a cutter bar in the clearing operation (A. Norrington *pers.comm.*) As the areas were then also cropped for several years, the few NVR survivors were ultimately killed. Most of those areas are still relatively NVR free today.

The second factor is the size of the cleared area and the distance to outside seed sources. Trees usually have a seed fall up to a distance of about three times their height. Any cleared area within this zone will be susceptible to NVR. It is better to have larger squarer paddocks with less perimeter per area than longer rectangular paddocks with more perimeter per area. This will lessen the area of cleared land susceptible to regrowth from seedlings.

The third factor is the actual layout of cleared areas and the positioning of tree strips, clumps or individual trees. If trees are retained in an open woodland manner it does not take long for seedlings to emerge throughout the whole area. If only 6 trees/ha are retained it is the same as having a full coverage of trees in terms of the potential for native vegetation regrowth (Burrows *et al*.1988). Burrows *et al* (1988) suggests the use of strips of 100m width to provide shade and shelter for livestock. These shade strips should separate cleared areas of between 400 – 800 metres width.

The invasion of woody plants into grasslands.

Another issue which needs to be considered is the invasion of grasslands by trees and shrubs and the thickening of woodlands and forests. There are large areas of floodplain which are not affected by NVR from clearing but rather from a thickening or invasion of native vegetation (T.Searle pers.comm, M Westbrooke pers comm..). This thickening is a result of interference with the normally occurring late dry season or early wet season fires. The usual practice of conducting early dry season burns is not conducive to the destruction of seedlings or juvenile plants. As a result they become very well established. Eventually they reach such a stage that even a very hot late dry season fire will not cause their death. The actual timing (i.e. at what interval) of fires to prevent the thickening or invasion of native plants is not yet known. This timing is of major importance as it would be necessary to exclude stock from the area to be burnt to ensure adequate fuel was available for a sufficiently hot fire. The current system of permits means that the only legitimate way of removing native vegetation from the floodplains is through fire. The question then becomes at what stage does the thickening of vegetation impinge so much on pasture production that the invaders must be removed? The other side of the equation is that if the invaders are left to become too big the fire may not be able to kill them. Also if the vegetation is too dense there may not be enough fuel produced to carry a sufficiently hot fire. This problem could be overcome if herbicides were used to scorch the invaders before burning. The problem here then becomes the obtaining of a clearing permit to use herbicides for what is in effect the clearing of the area.

Control options.

There are many options available for the control of NVR. A full list is provided and the merits of each control method will be discussed although some of the methods will not be acceptable where improved pastures need to be retained.

1. **Manual.**
   - **a.** Hand pulling.
     This method is only suitable for small numbers of easily removed plants. It is not really applicable to the project areas.
   - **b.** Ringbarking.
     This method is suitable for small areas of larger trees. There can be a delay in the death of the plant. For some species there is a tendency for them to coppice. This would totally negate the value of the initial operation and would in fact cause an increase in the number of stems to be dealt with by other means.
   - **c.** Grubbing.
     This method involves the use of a pick, mattock or spade to physically remove or grub out the plant including any roots or lignotubers. It is time consuming and would only be worthwhile for small numbers of reasonably small plants.
2. **Environmental.**
   - **a.** Grazing.
     Many plants can be suppressed through grazing pressure. However most of the problems with NVR in the Douglas Daly and Mary River districts involve plants that are unpalatable. The use of goats which can be successful in some areas in southern Australia would not be suitable in the two districts because of dingo predation and ironwood poisoning.

b. Pasture suppression.
If pastures are maintained in a healthy condition the emergence of NVR seedlings can be suppressed. Many pasture species produce allelopathic exudates. These help to suppress seedling emergence and growth (Miller 1988, Monaco et al 2001). A combination of spot spraying of any seedlings that do emerge along with careful grazing practices should be sufficient to achieve control of NVR on lightly infested paddocks.

3. Chemical.
This involves the use of herbicides to kill the NVR (Schultz, 1987a, 1987b; Schultz and Kernot, 1986). There does not appear to be any one chemical which will control all NVR. For this reason it may be necessary to use a cocktail of different herbicides and a variety of methods to obtain complete or adequate control. There are many different methods available to apply herbicides to NVR. There is probably a place for all of the different methods for the control of NVR as there are so many different combinations of size and density of NVR all of which require different control measures.

a. Foliar application.
As its name suggests this involves the application of a herbicide mixed with either water or diesel to the foliage of the plant. The mixture is sprayed over the foliage to the point of runoff. The mixture may be applied using a spot spray for light infestations, a hose and handgun running from a larger tank for targeted applications or a boom spray for the blanket spraying of a heavily infested area. For heavily infested areas it is also possible to use a fixed wing aircraft or helicopter to apply the herbicide aerially. For areas which are harder to access, such as along fencelines, the use of a boomless spray will enable the NVR to be sprayed quite effectively.

b. Stem injection.
This method involves the application of the herbicide into the sapwood of the plant (Whitford *et al* 1995; Dow 2007, Oosterhout 2003). It can be a useful treatment on larger regrowth that is too big for the cut stump treatment but too small or too sparse to be removed by chaining. Horizontal cuts are made with a narrow bladed axe or tomahawk (5-7cm wide) through the bark of the plant into the sapstream. The cuts are applied at waist height with a centre spacing of 10-13 cm. The axe is left in the cut and the herbicide is immediately placed down the blade using a stem injector. The injector is preset to deliver the correct dose at each application.
Another method of stem injection is the use of a drill to make a hole 5mm in diameter and about 5cm deep. The hole is then filled with the appropriate herbicide. The holes are drilled at spacings of 5cm (Oosterhout 2003).

c. Cut stump treatment (Ensbey 2002a,2002b).
This treatment is used for plants that are too small to be stem injected (Dow 2007, Oosterhout 2003). The stem of the plant is cut close to ground level (10-15 cm above ground level maximum). The stump is then immediately sprayed with the herbicide mixture. There can be no delay in spraying as the plant quickly seals off the cut preventing the entry of the herbicide. There are commercially available implements consisting of a brushcutter with a small tank and spray unit. This enables the spraying of the stump immediately after cutting.

d. Basal bark spraying (Ensbey 2002a,2002b).
In this method the herbicide is mixed with diesel to allow the herbicide to penetrate the bark. It is not suitable on bark that is wet or charred. The entire stem is sprayed to a height of 30 cm for each 2.5cm stem diameter. It is advised for regrowth up to 5-7.5 cm in diameter (Dow 2007, Oosterhout 2003, Back and Fosset, undated).

e. Herbicide applied to the soil (Dow 2007; DuPont).
There are a group of herbicides that are applied directly to the soil under or around the target plants. The herbicide is then absorbed by the roots of the plant. For larger areas it is usual to use a fixed wing aircraft to apply the herbicide. There are many advantages to using aerially applied herbicides to control NVR. One of the main advantages is that there is absolutely no ground disturbance. The standing timber is also not knocked down until much later, if at all, giving animals and birds in the area the opportunity to move. Tebuthiuron the active ingredient of Graslan® can be applied by hand for small numbers of plants or by air for larger areas. Hexazinone is applied as a liquid directly to the soil. A spear is used to penetrate the soil and dispense a pre set dose.

f. Wick wiper (Harrison, 1996; Price and Shotton 1997,2006, Gibson *et al* 1984).
A wick wiper is basically a piece of felt or rope wick which is soaked with a fairly concentrated herbicide mixture. The wick is wiped on the target plant which is usually raised above the pasture. This passes the concentrated herbicide onto the target plant. This method is very good if the herbicide flow can be adjusted to ensure that no non target plants are contacted. The wick wiper could be used in this project for scattered plants however it would have to be a small hand held wick wand. The larger tractor towed wick wipers available today would not be suitable as the NVR would be too rough on the wick and would soon damage it.

g. Carpet roller (Price and Shotton 1997,2006; Gibson *et al* 1984; Bovey and Meyer, 1989; Shotton and Hazel, 2003).
As the name suggests this machine consists of a roller covered with a carpet. Concentrated herbicide is applied by a delivery system to keep the carpet wet but

not over saturated as any dripping will kill non target plants. There are many advantages when using a carpet roller. These include:

- Less herbicide used leading to cost savings.
- More environmentally friendly as there is no soil contact of herbicide and no spray or wind drift.
- Ability to use broad leafed plant herbicides even in a legume pasture with no damage to the pasture.
- No off target damage.
- Requires less water than boom sprays.
- Cheap and easy to construct.
- Easily towed.

There is only one real disadvantage in using the carpet roller. This is the need for the target plants to be taller than the pasture. This will necessitate grazing the paddock to a state where the height of the nvr is well above the pasture before it can be wiped. If there are sufficient cattle on the property it should be possible to treat one paddock per day or else wait for several paddocks to be grazed and then treat them in one operation. The use of large numbers of livestock to graze the pasture and expose the weeds or NVR to the herbicide has already been adopted by some producers in the Douglas Daly district (C. Muldoon, per comm.).

4. Mechanical.

a. Slashing (Andersen and Scanlan, 1986; Oosterhout, 2003; Scanlan and Pressland 1984)

Slashing is one of the simplest methods of suppressing smaller NVR. It usually takes many cuts to actually kill the NVR however it is one way of keeping the plants to a manageable height (R. Fremlin pers comm., Scanlan and Pressland 1984, Monaco *et al* 2001). Slashing could be combined with the use of herbicides to deplete the reserves in the plants' roots or lignotubers leading to the death of the plants (G. Atkinson, pers comm., Monaco *et al* 2002). One major advantage in the use of slashing as a control measure is the total lack of soil disturbance. Slashing would also be helpful in cutting taller NVR down to a height that would allow the use of a carpet roller.

b. Chisel ploughing.

The chisel plough is designed to shatter the soil but not to turn or move it. If the chisel plough is fitted with wide sweeps it is capable, in soil which is dry to moist, of cutting through plant roots and lignotubers. In a trial in Queensland an area which was stick raked and then chisel ploughed achieved a kill of currant bush (*Carissa ovata*) of 76.8%. There were only two other treatments which achieved a better result. These were: tebuthiuron (Graslan®) @ 2.0kg a.i./ha with 77.7% kill and stick rake then blade plough which gave a100% kill (Back 1998).

c. One way plough.
The one way disc plough completely inverts the soil burying all plant material. It is capable of cutting through NVR and if conditions are right it can give a reasonable kill (B Beumer pers. comm. Scanlan and Pressland 1984). However if there are follow up rains after ploughing its success is greatly diminished. The level of soil disturbance is much greater with a one way plough than with a chisel plough.

d. Offset disc plough. (Scanlan and Anderson, 1974)
The offset disc plough consists of two rows of discs which turn the soil in alternate directions. Their use for NVR control is limited as they tend to bury the plant material with the first row of discs and then expose it with the second cut. Back's (1998) trial in Queensland only achieved a 39.2 % kill with a treatment consisting of a preliminary stick rake operation followed by the offset disc plough. The level of soil disturbance with the offset disc plough is also a major disadvantage. The offset disc is not considered to be of any value in an NVR control program.

e. Blade plough. (Harland undated; Scanlan and Anderson 1981; Scanlan and Pressland 1984; Anderson and Scanlan 1986; Bastin 1989; Back 1998; Bohning 1999).
A blade plough may consist of a swept back blade supported by a single tine or for wider ploughs it may have up to three blades each supported by their own tine. The plough operates by cutting through the ground at a predetermined depth to cut through roots, stumps and lignotubers. The depth of cut is a very critical factor in the success of the operation. If the cut is too shallow it may not cut off the roots or lignotubers. Regrowth will then occur from these plant parts. The recommended depth of ploughing is 30-35cm. In a trial conducted by Back (1998) an area that was stickraked and then blade ploughed had a kill rate on currant bush of 100%. This rate compares with Tebuthiuron that had a kill rate of 77.7%
One of the major problems with the blade plough is ensuring that the blade is able to penetrate the ground to the required depth. However if the soil is too moist there is a likelihood of the cut off roots or lignotubers reshooting (Vitelli 2000). The best time to blade plough is immediately after the wet while there is still sufficient moisture to allow the blade to penetrate but not enough moisture to allow the cut off plant parts to reshoot. Blade ploughing leads to quite extensive soil disturbance. It would not be suitable in a well established healthy pasture. It would however be good for the restoration of native pasture or degraded improved pasture. Blade ploughing may not be appropriate on slopes of greater than 1%. However areas of land, on a local property, with a slope well in excess of 1% were

recently blade ploughed and then aerially sown with improved pasture. There was no apparent soil loss and the pasture is now well established. It may be possible to blade plough a large area of steeper country if it is done in strips. The size of the strips and the area left between would be determined by the slope of the land and the erodibility of the soil. On steeper country or more erodible soils the Ploughed strips would need to be narrower with a wider strip left between. Another option would be to construct a system of graded banks and waterways to protect the soil. The spacing of the banks would depend on the slope of the land and the soil type as well as future management plans.

f. Cutter bar (Scanlan and Pressland 1984).
A cutter bar consists of a cutting blade between two ripper tines. The cutter bar penetrates the soil to a sufficient depth to cut through the root systems or lignotubers. Cutter bars were used extensively in the Douglas Daly district in the early days of the ADMA development. Most of the area where a cutter bar was used is still free of NVR. Cutter bars would have a place in the control of NVR however the same constraints that apply for a blade plough would apply to the cutter bar although it would not disturb the soil or the pasture to the same extent.

g. Pushing (Bastin 1989; Scanlan and Pressland 1984).
Native vegetation regrowth may be pushed with a dozer using either a blade or stick rake. This method is only worthwhile when the soil is moist. If the ground is dry the NVR will either snap off or just lay down. It may be an option on small areas of NVR if there is a dozer on the property however for larger areas it would not be worthwhile.

h. Stick raking (Scanlan and Pressland 1984; Anderson and Scanlan 1986; back 1998; Bastin 1989; Michelmore 1997)
A stick rake consists of a fingered blade that either bolts onto or replaces the existing blade. Stick raking can be suitable for removing larger NVR however it is fairly slow and fairly expensive (Bastin 1989). For extensive areas of smaller flexible NVR it would not be suitable. In a trial on currant bush (Back 1998) the result achieved with a stick rake used in one direction was 1% kill. The result with a stick rake used in two directions was 56.3%.

i. Finger wheel raking (Bastin 1989)
Towed finger wheel rakes of heavy construction are suitable for cleaning up country that has already been chained or windrowed. They would be useful to clean up any remaining logs, stumps, sticks or roots. They can either sweep the remaining timber out of the area or into a smaller windrow in the centre of the paddock. Finger wheel rakes would not be of much use in areas of small whiipy NVR.

j. Mechanical grubber (Bontrager *et al* 1979; March and O'Leary undated).
There is no reference in the literature to the use of mechanical grubbers in the project areas. However mechanical grubbers have been used both overseas and in Australia with some success. The grubber consists of a cutting blade mounted on a frame. It can be rear mounted or front mounted. A mechanical grubber in western NSW was mounted on a front end loader. The operator was able to grub out 300 plants per hour using this machine (March and O'Leary). If suitable machinery was available in the project area this technology may warrant consideration.

k. Roller chopper (Bozzo *et al* 1992; Schindler and Fulbright, 2003).
The roller chopper is used as a knock down tool only. It's advantages and limitations are the same as for slashing.

l. Chainsawing (Oosterhout, 2003).
Chainsawing by itself would only be a temporary control measure. However a chain saw is very useful when used in conjunction with herbicides in the cut stump treatment.

m. Crocodile pitter/pitting roller.
The crocodile pitter consists of a hollow steel cylinder with shovel shaped steel plates welded at intervals on the surface. The crocodile pitter is useful for knocking down smaller trees and shrubs. The pitter would be suitable for rehabilitating pasture as seed can be placed in the roller and released through holes at the base of the shovels.

n. Chaining.
A heavy chain dragged between two tractors or bulldozers can be used to knock down regrowth. The main limitation of chaining is the need to wait until the regrowth is of a sufficient size to allow it to be uprooted. If the regrowth is too young or "whippy" it may simply lay over without being uprooted. To achieve a better result a second chaining in the opposite direction to the first will often completely uproot the regrowth. Chaining by itself will not give a complete kill but as it is a very cheap option it could be repeated every 4-5 years with a very small average annual cost.

5. Fire.

Fire has a very significant role to play, in many areas, in suppressing NVR and also in preventing the thickening of existing woody vegetation (Bastin undated; Anderson and Scanlan 1986; Anderson and Pressland 1987; Bowman *et* al 1988; Burrows *et al* 1988; Bastin and Andison 1990; Cook and William 1995; Daly and Hodgkinson 1996; Craig 1997; Noble 1997; Campbell and Setter 1999; Craig 1999; Bastin *et al* 2003;).

The use of fire to control or suppress woody plant growth is well documented for many other areas. However there has been very little work done on fire in improved pastures. In one trial Mannetje *et al* 1987 studied the effect of fire on a buffel grass and siratro pasture. They determined that there was no long lasting effect on the pasture. This information is relevant for the Douglas Daly district where buffel grass has been planted over large areas. Work by Falvey (1977) at Douglas Daly Research Station showed that even after a hot fire in June there was quite extensive regrowth of improved pastures. Falvey (1977) looked at the dry matter production of sabi grass (*Urochloa mosambicensis)*, buffel grass (*Cenchrus ciliaris*), pangola grass (*Digitaria decumbens*), verano (*Stylosanthes hamata cv.* Verano), leucaena (*Leucaena leucocephala*) and a native grass species sehima (*Sehima nervosum*). His work showed that there was a marked difference in crude protein yield between the improved pasture species and the native grass. The main point of interest in this research however is the survival of all of the improved pastures and even an increase in crude protein levels after a fire. This opens up the possibility of the use of fire as a management option for NVR.

For fire to be used as an effective measure for controlling NVR certain conditions need to be met.

- The NVR should be no more than 2m high. If the regrowth is higher than 2m the percentage of plants killed drops significantly (Bastin 1989; K. Springall *pers comm.*).
- The weather conditions need to be correct (Bastin 1989). High temperature, medium wind speed and low humidity will give the best result and produce an intense hot fire that should kill off most of the NVR (T. Searle *pers comm.*)
- High fuel load. There needs to be sufficient fuel to carry the fire and generate enough heat to kill the NVR (Bastin 1989).
- Uniform fuel load. The fuel load needs to be the same over the whole area. If the fuel load is patchy the resultant burn and NVR kill will also be patchy (Anderson and Pressland 1984).

Fire has been used extensively in Australia for the control of woody plants in rangelands. It is surmised that a large area that is now woodland or forest was previously grassland. The changes in fire regimes brought about by man have allowed plants that were once controlled by late dry season hot wildfires to encroach into areas where they could not normally survive. Many seedlings and juvenile plants could not survive the late dry season or early wet season wildfires. However they can survive the cooler early dry season fires which are employed by pastoralists to rejuvenate their pastures and provide firebreaks through fuel reduction. Many researchers are of the opinion that the encroachment of woody plants into grasslands and the thickening of woodlands is a significant carbon sink. However the question here is the role of fire in controlling NVR. One of the problems in using fire as a control measure is that a good hot late dry season fire requires adequate fuel. To obtain this fuel it is necessary to remove grazing pressure. This means that for the area to be burnt there can be no production for perhaps two years. The first year involves removing grazing pressure to build up the fuel load. Once the area has been burnt it needs to be spelled for the next year or perhaps even the following year to allow the pasture to recover from the fire. The cost of lost production for 2 or 3 years may make this option unviable. A further problem with the use of fire as a control measure for NVR is the potential for soil erosion. The time to burn for the best result in controlling NVR is in September or early October. A good hot fire will however probably remove most of the ground cover. This will expose the soil to the early wet season storms leaving it vulnerable to erosion. Once a vegetative cover has established the erosion risk will diminish quite significantly.

6. **Biological.**
   In this project we are dealing with native vegetation regrowth. Any attempt at biological control is obviously not possible as any biological control agents will have the potential to affect non target plants. Although the two biological control agents have been listed, for the sake of completeness, they will not be investigated further.
   a. Insect.
   b. Pathogen.

7. **Combination.**
   There are many combinations of different control measures that could be used to kill or suppress NVR. One of the most widely researched in Queensland is the combination of herbicides and fire. Johnson and Back (1977a,b) looked at the use of spraying both before and after fire. In both cases there was a significant improvement in mortality rates. Noble (1992), Noble *et al* (1991,1992, 1999, 2002 and 2005) looked at the use of low concentrations of herbicide after fire to simulate a second fire. The thought was that low concentrations of chemical would provide the same effect as a fire without having to wait for the build up of fuel. A quicker turn-around of control measures also allowed the area to be brought back into production much quicker. The effect of fire on biodiversity in the project areas is not known. However studies in Kakadu have shown that many species are dependent on fire. Whether this would be the same for grazing lands with native pasture or improved pasture would require further research. The use of fire with a follow up application of herbicide should perhaps be trialled.
   Mention has also been made of the use of slashing or chopper/rolling followed by the application of herbicides to kill NVR (R Fremlin *pers comm.*,Monaco *et al* 2002) In Fremlin’s work the herbicide was applied by handgun to the few remaining isolated plants. A slasher would be preferred to a chopper roller as the chopper/roller destroys most of the pasture.
   Monaco (2002) mentions the use of repeated cutting or defoliation as a means of killing NVR. The object of this repeated cutting or defoliation is to use up the plants’ food reserves until they die. It may be possible to slash the NVR, wait for it to reshoot and then treat it with a herbicide. If the herbicide is applied before the NVR has fully

recovered from being slashed the chances of a successful kill would be greatly increased. If it is found that slashing once then spraying does not give an adequate control it may be necessary to slash twice before applying herbicide.

Previous trial work in the project areas and other related work.

There has been very little published research into the control of native vegetation regrowth in the Douglas Daly and Mary River districts. The earliest trial was undertaken at Tipperary Station in 1965-1967 by B. Frank for the A.M.R.C. Frank undertook six mechanical and three chemical treatments. The mechanical treatments comprised: ripping, ploughing and ripping and ploughing at two different times. The ripping was done at a depth of 60cm. The ploughing was done to a depth of 15cm. The chemical treatments used were: Ammate X, 2,4,5-T and Tordon 50D. Overall none of the treatments was successful. With the results of further work done elsewhere it is now known that ploughing to a depth of only 15cms is not enough to cut through the roots and lignotubers. The herbicides were also ineffective although they did kill some of the NVR. One species which was not controlled in any trial was ironwood (*Erythrophleum chlorostachys*). For the project it will be necessary to conduct herbicide trials that specifically target ironwood.

Another early trial of relevance to the project was undertaken in Kununurra in 1963 (van Rijn 1965). This trial showed that it was possible to get a good kill of regrowth if it was sprayed while it was still young. However because the plants were sprayed before all of the regrowth had emerged a further round of spraying was required. Some of the herbicides trialled are still available today, although they have been replaced by a range of herbicides that are cheaper, more effective and have less impact on the environment. In this trial no chemical was found that controlled ironwood (*Erythrophleum chlorostachys*). It appears that ironwood is one species that has always presented problems and needs to be targeted in this project.

A trial using Crossbow® was started in the Mary River district in 2005 (Eastick *et* al) to determine its efficacy. Crossbow was a two part mixture of metsulfuron-methyl and picloram. As it is no longer available the trial was never completed.

A further trial comparing glyphosate, metsulfuron-methyl, and glyphosate and metsulfuron-methyl was undertaken in 2006 (Hartley *et al*) in the Douglas Daly district. There were 9 different combinations and rates trialled and compared with the commonly used Grazon DS®. None of the trialled rates or combinations was anywhere near as good as the Grazon DS®

Discussion of regrowth scenarios and control options for each.

There is no point of discontinuity in the size or density of regrowth where it could be said that there is an abrupt change in control options for a particular size or a particular density. Both of these factors proceed in a linear progression. To make it possible to discuss control options it is necessary to assign arbitrary boundaries to various sizes and densities of regrowth. There are also areas where there is a transition from one control option to another within a particular scenario. This usually occurs in the medium size and medium density ranges. Within these scenarios it may be possible to use a control option at the lower density or smaller size that is not viable at a greater density or larger size. Where this transition point occurs it has been noted. Following on from discussions with Ken Springall of Dow AgroSciences the following range of sizes and densities has been selected. These size and density ranges although arbitrary allow a determination to be made of the available range of control options for each scenario. There are valid reasons for these determinations. It is believed that once regrowth is taller than 2m it is very hard to control with either fire or foliar applied herbicide. Plant densities also determine whether it is economically viable to use hand applied herbicides. If there are 200 plants per hectare it would be possible to use hand applied control methods. If the density is 2000 plants per hectare hand application is no longer an option.

The range of regrowth sizes is:

1. Small < 2m,
2. Medium 2-5m
3. Tall > 5m.

The range of densities is:

a. Scattered <200 plants per hectare
b. Medium 200-600 plants per hectare
c. High >600 plants per hectare.

The suggested control options for each scenario are:

1.a. Small/scattered

- Carpet roller
- Handgun-foliar
- Basal bark
- Hand applied Graslan®
- Velpar® - spot application
- Fire
- Grubbing – hand or mechanical
- Slashing

1.b. Small/medium

- Carpet roller
- Fire
- Velpar – grid 2m x 2m
- Graslan – hand applied (lower density)

- Graslan – aerial (higher density)
- Grubbing - mechanical
- Foliar spray – hand application (lower density)
- Foliar spray – aerial (higher density)

1.c. Small/high density

- Blade plough
- Carpet roller
- Graslan® - aerial
- Foliar – aerial
- Fire- depends on body of fuel.

2.a. Medium/scattered.

- Stem inject
- Basal bark
- Cut stump
- Velpar- grid 2m x 2m
- Graslan – hand applied
- Fire – species dependent. Fire will work well on medium size acacias, but not on medium sized eucalypts.
- Grubbing - mechanical

2.b. Medium/medium

- Blade plough (higher density)
- Chaining (taller plants only 4-5m)
- Mechanical grubbing (lower density)
- Graslan® - aerial
- Velpar – grid 2m x 2m
- Stem inject (lower density)
- Fire (smallest only)
- Cut stump (lowest density only)

2.c. Medium/high

- Blade plough
- Chaining (taller plants only 4-5m)
- Graslan® - aerial

3.a. Tall/scattered.

- Cut stump
- Stem inject

- Velpar – spot application
- Graslan – hand application
- Grubbing – mechanical

3.b. Tall/medium

- Blade ploughing
- Chaining
- Grubbing – mechanical (lowest density)
- Graslan – aerial
- Velpar – grid 2m x 2m (expensive)
- Stem inject (lower density)
- Cut stump (lower density)

3.c. Tall/high

- Blade plough
- Chaining
- Graslan – aerial.

From the above list it can be seen that there are many different scenarios to assess. It is not possible to assess them all with the resources available and within the constraints of existing land clearing application requirements. The proposed trials at the present time are presented in appendix 1

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Appendix 1

Suggested trials for the project.

As previously mentioned one of the main species presenting regrowth problems is northern ironwood (*Erythrophleum chlorostachys*). It has been suggested that one way to lessen the regrowth potential of any species is to kill all adult trees before the area is pulled (G Schultz *pers. comm*.). This would involve treating the adult tree via stem injection. Information on suitable herbicides to control ironwood is not available. As ironwood is toxic and even small amounts are sufficient to kill livestock it is considered appropriate that trials to determine a suitable herbicide to kill ironwood be undertaken. The trials will target larger regrowth with stem injections and smaller regrowth with foliar and/or basal bark applications. A range of herbicides will be trialled. The following range has been suggested by Ken Springall of Dow AgroSciences.

Foliar spray (for ironwood regrowth less than 2m tall):

- Grazon Extra®
- Starane®
- Lontrel®
- Metsulfuron-methyl
- Garlon®

Stem injection (for ironwood taller than 4m)

- Tordon DSH®
- Tordon DSH® + metsulfuron-methyl
- Hexazinone *
- Glyphosate
- Glyphosate + metsulfuron-methyl
- Lontrel®
- Starane®
- 2.4 D – Amide
- Dicamba
- Unimaz
- Arsenal Express

The full range of herbicides will be applied to tagged plants in October/November 2009. To help determine whether time of application is relevant a further treatment will be undertaken in March/April 2010.

Grazon Extra® is considered the herbicide of choice for regrowth control. However there are some species which do not appear to be controlled adequately by this herbicide. To determine which species are not controlled and also to determine whether time of application is relevant the following trials will be undertaken.

Grazon Extra® will be applied as a foliar spray to most of the main species found in both the Douglas Daly and Mary River districts in October/November 2009. This will be repeated in March/April 2010.

From the results of the October/November 2009 spray it should be possible to determine which species have not been killed by the Grazon Extra®. These species will then be sprayed with a range of herbicides in March/April 2010. This range of treatments will be repeated in October/November 2010 to determine whether time of spraying is relevant. The herbicides to be used will include:

- Metsulfuron-methyl
- Lontrel
- Garlon
- Starane
- Glyphosate.
- Metsulfuron-methyl/glyphosate

A trial/demonstration of the effect of using Access® with diesel @ 1:60 will be carried out using both the cut stump and basal bark spraying treatments. These treatments will be carried out on the major species of plants present in both the Douglas Daly and Mary River districts. The treated plants will be tagged and recorded. The results of the treatment will be observed at the end of the wet season (April/May2010) and again at the end of the dry season (S. A further observation may be undertaken at the end of the following wet season (2011). It is proposed that this work will demonstrate whether new regrowth that appears the following year is sprayed regrowth that has reshot or new regrowth from seeds or buried roots/lignotubers.

One of the main aims of the project is to measure the impact of various treatments on biodiversity. The area required to undertake scientifically valid trials is a minimum of 16 hectares. The actual trial site will be 400 m x 400 m with a 250m band of untreated regrowth around the site. The trials to be undertaken will be:

- Blade ploughing (flatter country)
- Graslan (aerial application)
- Burn then spray or carpet roll after regrowth re-establishes.
- Slash then spray or carpet roll after regrowth establishes.
- Slash, then slash again after next flush of growth, then carpet roll after regrowth has recovered.

To measure the impact of each treatment on biodiversity there will be three subplots 50m x 50m within each treatment plot. There will also be a subplot in the untreated strip left around each treatment plot. 10 samples of invertebrates will be collected at each subplot using buried jars containing ethanol and glycol. The invertebrates collected will be identified to the level of orders.

To determine the effectiveness of the various treatments, measurements of plant mortality and/or browning off will be taken. Fixed transects will be set up throughout the trial sites to cover all tree species found throughout the sites. Records will be taken before treatment and then at intervals over the next 18 months. Points will be given for different levels of browning off or death and the results compared for different species and different treatments. The proposed list is able to be adjusted if any stakeholder has a particular trial that they would like to see included. If there is an area that you would like to see covered please reply via e-mail and if possible it will be included in the program.